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I.E.S.
RESOURCE CENTRE

Research Publication No. 90

July, 1982

Ontario
Ministry of the Environment

The Honourable
Keith C. Norton, Q.C.,
Minister

Gérard J. M. Raymond
Deputy Minister

EVALUATION OF THE PERFORMANCE OF A COMBINED SEWER OVERFLOW RETENTION TANK

I. E. S.
FEB 10 1989
RESOURCE CENTRE

BY

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WASTEWATER TREATMENT SECTION

POLLUTION CONTROL BRANCH

ONTARIO MINISTRY OF THE ENVIRONMENT

RESEARCH PUBLICATION NO. 90

JULY, 1982

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The draft of this report was reviewed by M. Fielding, J. Marsalek, Z. Novak, K. Roberts and P. Seto to whom the writers' thanks are due.

SUMMARY

The performance of the combined sewer overflow tank near Hyde Avenue in the Borough of York was studied in the summer months (June to October) of 1977 and 1978. The entire study period spanned 276 days during which time 50 storms occurred. Thirty-three storm events produced inflow to the tank. Seventeen of these events were wholly retained within the tank with the remainder resulting in a total of 102.3 IMG of overflow to Black Creek.

The presence of the tank reduced overflow volume by 18%. Pollutant loadings for BOD, solids and nutrients were reduced by an average of 38%-47% of the influent loading including wholly retained events and events with overflow. The tank was, therefore, an effective device for reducing pollution from combined sewer overflow.

The outlet barrier of the tank removed practically all floating substances from the overflow to the creek, greatly enhancing the aesthetic quality of the overflow.

The information presented in this report is intended to benefit municipalities faced with the control of combined sewer overflows. The approach to performance evaluation used, and the performance data describing the pollution control effectiveness of the storage device, will aid in the design and compliance monitoring of similar future facilities.

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1.0 INTRODUCTION

A joint study was carried out by the Ontario Ministry of Environment and the Borough of York in Metropolitan Toronto to assess the performance of the combined sewer overflow (CSO) detention tank near Black Creek in the summer months (June to October) of 1977 and 1978. The above tank intercepts the flows from the tributary combined sewer system when the flowrate in the sewer system exceeds a predetermined limit. The tank retains that fraction of the intercepted flow not exceeding its own capacity and overflows the remaining fraction after sedimentation to Black Creek. The flow retained by the tank is subsequently returned to the sewer system. This report presents the findings of the study.

2.0 OBJECTIVE AND SCOPE

The objective of the study was to assess the effectiveness of the CSO tank in reducing the quantity and in upgrading the quality of overflows to Black Creek. Work was concentrated on obtaining precipitation data and the quantity and quality of sewer system and tank influent and effluent flows under dry and wet weather conditions. The study also characterized the catchment and the sewer system and examined their response to the climatology of the monitoring period.

3.0 BACKGROUND

3.1 General

The catchment area shown in Figure 1 is a relatively older section of Metropolitan Toronto. It has an area of 2,060 acres and an estimated population of 70,000. Although fully developed some time ago, redevelopment had commenced in the late sixties to meet the needs of the increasing population brought by social and economic growth.

Nearly the whole catchment area was and still is serviced by a combined sewer system, although sewers at some locations have been separated to reduce basement flooding problems. The combined sewer system discharges into the Metro Toronto Trunk Sewer (MTTS), which is tributary to the Humber Water Pollution Control Plant (WPCP). Before the combined sewer overflow tank was built,all flows in excess of the MTTS capacity had overflowed from several locations into Black Creek without treatment.

One option for the Borough to deal with the additional combined sewage generated by the urban redevelopment was to take on a sewer separation program. This option was expensive and it was realized that partial separation of the combined sewers would not significantly reduce overflows. In 1968,it was decided that rezoning and redevelopment could be continued only if the combined sewer overflows to Black Creek were chlorinated and detained in a holding tank before being discharged. The CSO tank was subsequently constructed and placed in operation in 1972, at an existing overflow location at the western end of Hyde Avenue on the east bank of Black Creek.

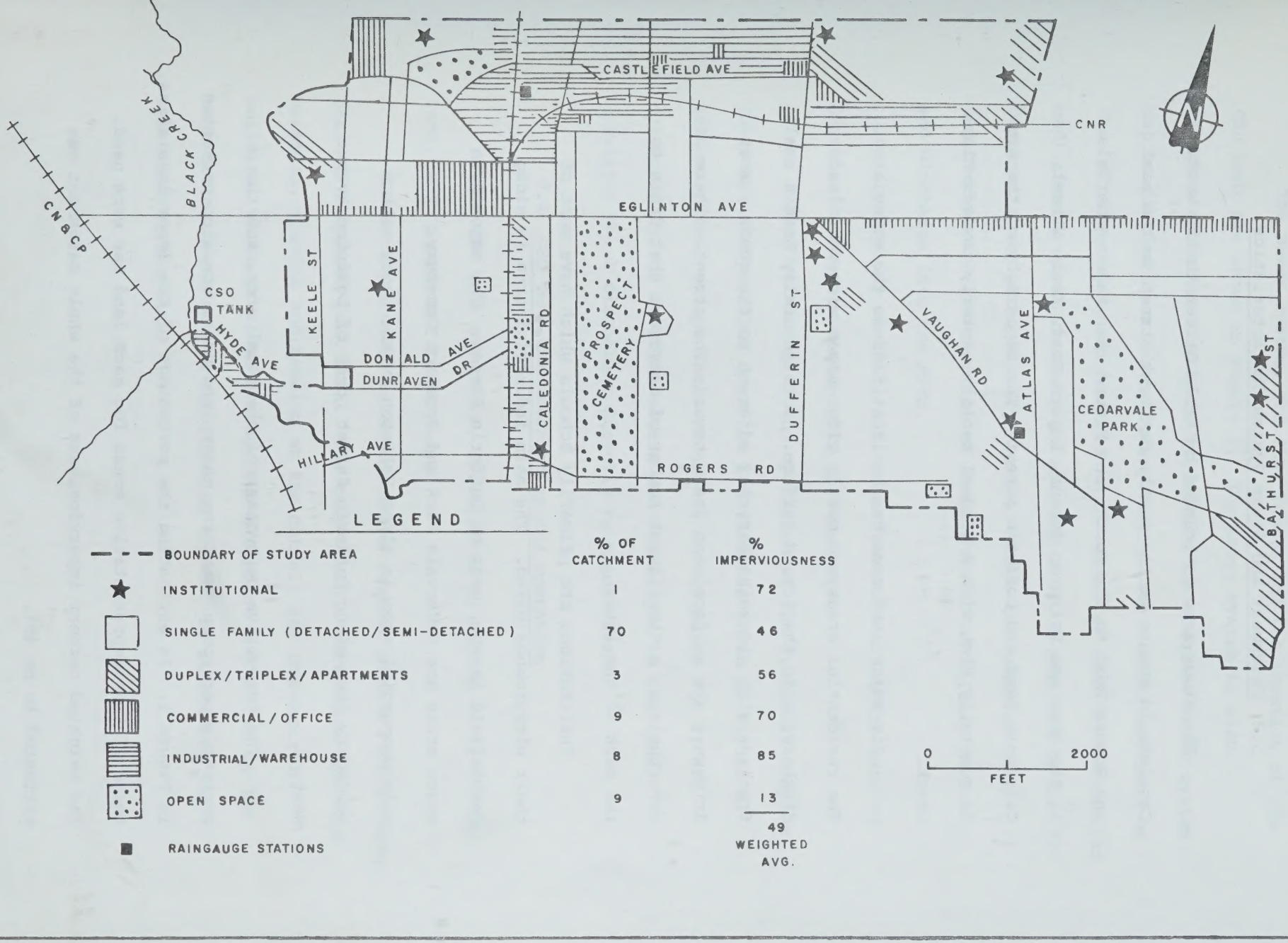


Figure 1 Hyde Avenue catchment area.

3.2 Catchment And Sewer System Characteristics

The study area is bounded by Keele Street to the west, Castlefield Avenue to the north, Bathurst Street to the east and Rogers Road to the south (see Figure 1). Major arterials in the area are Eglinton Avenue, Rogers Road, Keele Street, Caledonia Road and Dufferin Street. The topography of the area is generally flat with a gradual decline westerly towards Black Creek.

Six major land uses can be identified in the study area. The residential areas are mostly older homes with roof leaders discharging to the ground surface. Lots generally have a small frontage with sidewalks directly adjacent to the roads. Most driveways are surfaced and drain towards the street. There are, nevertheless, a significant number of driveways that drain to the back of the lots.

Institutions are primarily schools which have most of their playgrounds paved. The main industrial area is along Castlefield Avenue, west of Dufferin Street. The major open space areas are Cedarvale Park and Prospect Cemetery. The main commercial area is along Eglinton Avenue West, with a secondary area along Dufferin Street north of Eglinton Avenue West.

The respective percentage of the total area, and the percent imperviousness of the major land uses, are also presented in Figure 1. In estimating the percentage of the impervious areas, three of four representative areas for each land use were used. The weighted percent imperviousness of the whole catchment was estimated to be 49%.

The sewer system, the flow routes and the location of the CSO tank are shown in Figure 2. The sewer system is also illustrated schematically in Figure 3. The combined sewer system can be divided into two tributary areas; Area 1 being serviced by the 54" diameter sewer (reduced to 39" diameter near the downstream end) flowing south on Keele Street, and Area 2 serviced by the 72" diameter sewer along Hillary Avenue. These two branches join together at the intersection of Keele Street and Hillary Avenue and discharge into the MTTS.

During dry weather, all flows from both areas are carried by these two sewers to the MTTS and the WPCP.

During wet weather, the operation of the system is complex. There are six possible overflow locations as shown in Figure 3. All overflows, except those occurring at Regulator No. 1, are collected by the overflow sewers and discharged to the tank. Regulator No. 1 discharges directly to Black Creek.

3.3 CSO Tank Characteristics and Operation

The CSO tank structure, illustrated in Figure 4, is 178 ft long, 125 ft wide and 14 ft deep.

It is constructed underground and covered with a roof forming part of a grassed park area. The only visible structures are four manholes, grating and fencing at the outfall and the control building, which provides storage for equipment and access to the tank for maintenance. A chlorination chamber is located at the inlet end of the tank.

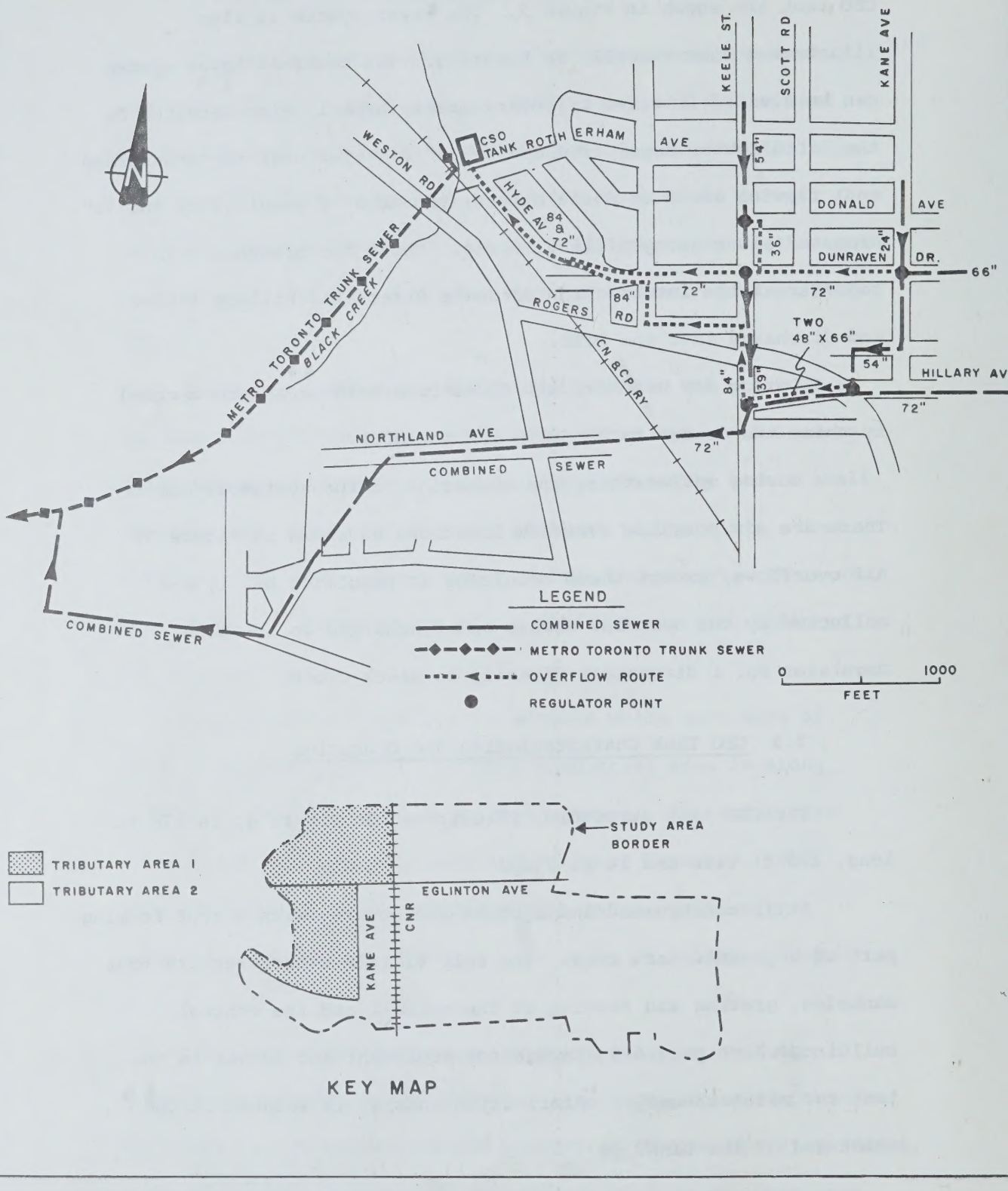
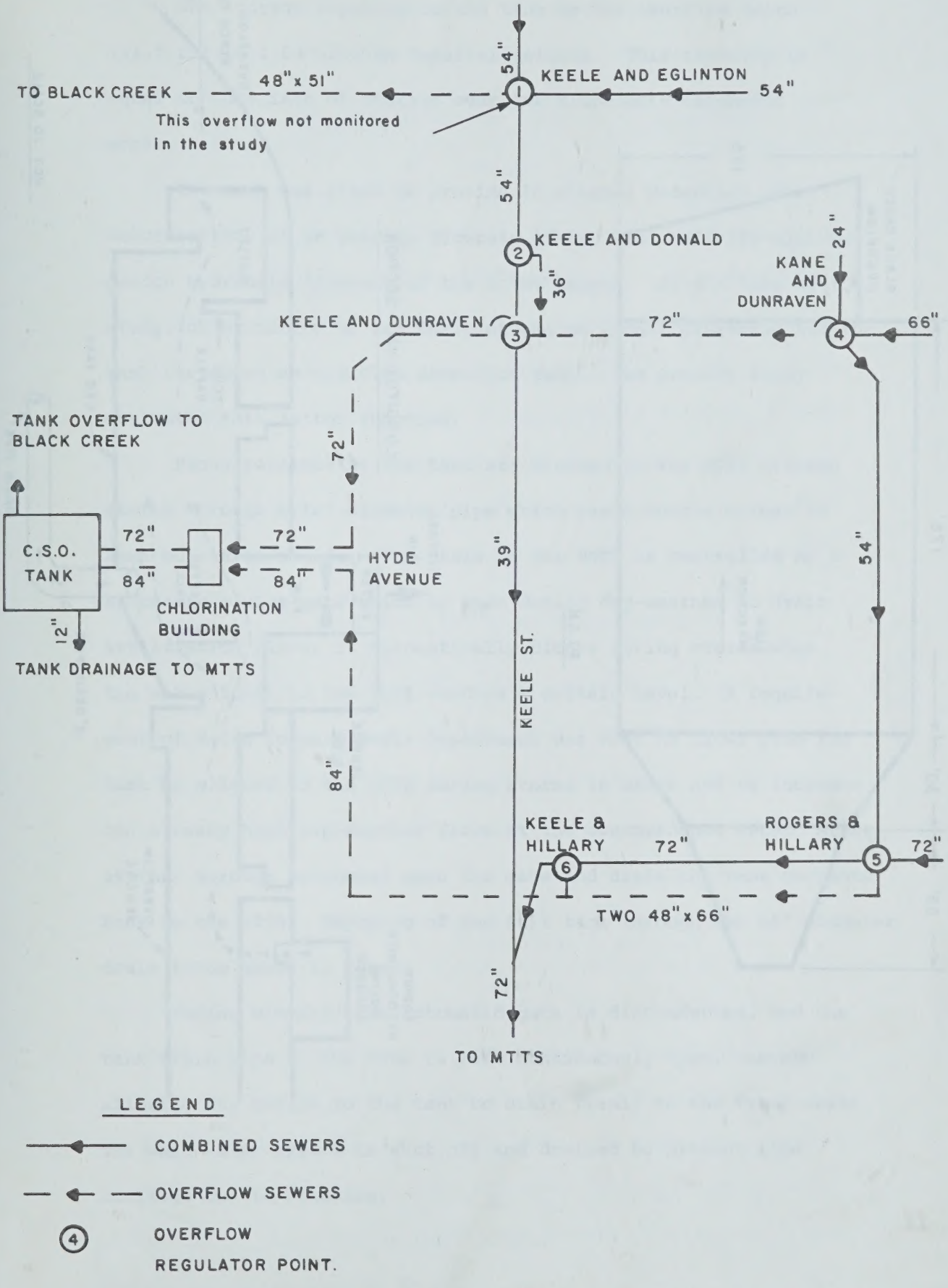
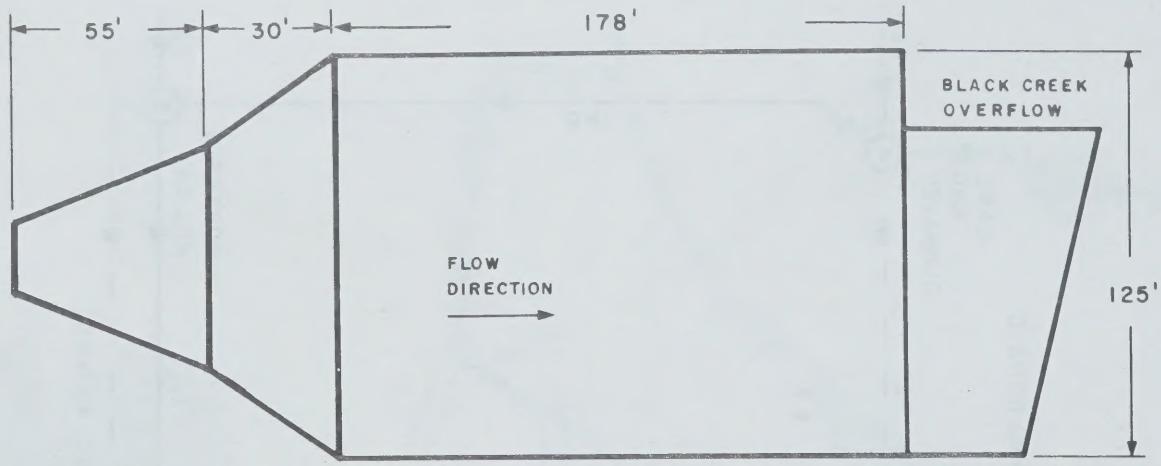


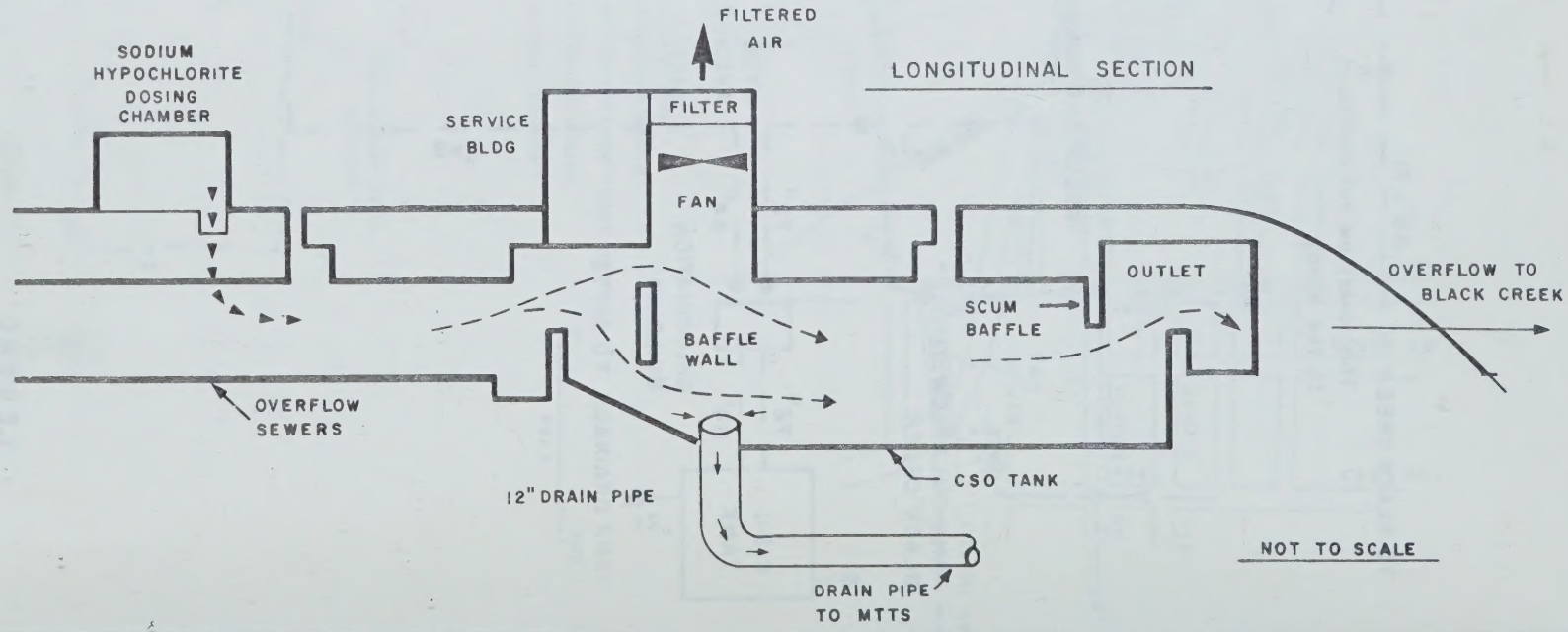
Figure 2 Tank location and flow routes.



igure 3 Diagram of flow regulating system.


55'
30'
178'
BLACK CREEK
OVERFLOW
FLOW
DIRECTION
125'

PLAN


FILTERED
AIR
LONGITUDINAL SECTION
SODIUM
HYPOCHLORITE
DOSING
CHAMBER
SERVICE
BLDG
FILTER
FAN
OUTLET
OVERFLOW TO
BLACK CREEK
SCUM
BAFFLE
BAFFLE
WALL
OVERFLOW
SEWERS
CSO TANK
12" DRAIN PIPE
NOT TO SCALE
DRAIN PIPE
TO MTTS

The storage capacity of the tank to the overflow depth (11.5 ft) is 1.63 million Imperial gallons. This capacity is equal to .035 inch of storage over the 2,060-acre catchment area.

The tank was sized to provide 10 minutes detention after chlorination, at an average flowrate of 500 cfs, half the maximum design hydraulic flowrate of the inlet sewers. At the time of the study, chlorination of the influent was no longer practiced and the tank served as an overflow detention tank. The present study evaluated this latter function.

Flows retained by the tank are drained to the MTTS between storms through a 12" diameter pipe which has a coarse screen to keep out large solids. The drain to the MTTS is controlled by a hydraulic sluice gate which is open during dry-weather to drain infiltration flows; it automatically closes during storms when the water level in the tank reaches a certain level. A requirement of Metro Toronto Works Department was that no flows from the tank be allowed to the MTTS during storms in order not to increase the already high wet-weather flows at the overburdened WPCP. After storms, Borough personnel open the gate and drain the tank contents back to the MTTS. Emptying of the full tank through the 12" diameter drain takes about 11 hours.

During winters, the automatic gate is disconnected, and the tank drain pipe to the MTTS is left continuously open, thereby allowing any inflow to the tank to drain freely to the trunk sewer. The wash water system is shut off and drained to prevent pipe breakage due to freezing.

The overflow end of the tank has a scum baffle which prevents floatable debris in the sewage from reaching Black Creek.

4.0 MEASUREMENT TECHNIQUES AND INSTRUMENTATION

4.1 Rainfall Measurements

The prevailing direction of summer storms in the Borough of York is from the west with storms at times being quite local. Accordingly, two raingauges were used to gather representative rainfall data. Precipitation data were collected by two tipping bucket recording raingauges. Rainfall was recorded on 24-hour charts with a time resolution of approximately 2.5 minutes. The locations of the two raingauges in relation to the catchment area are indicated in Figure 1.

4.2 Dry-Weather Sewer System Measurements

In-sewer flow measurements and samples were taken to determine dry-weather sewage quantity and quality. An attempt was also made to determine the minimum wet-weather flow producing overflows at the major regulators and to calculate the ratio of WWF/DWF producing overflows.

4.2.1 Quantity Determination

The ideal location for measuring the total dry-weather flow from the catchment area would be some point in the sewer downstream of the junction of Keele Street with Hillary Avenue. It was not feasible to measure the total flow conveniently at this location. As a result, flows were measured separately in the 72" Hillary Avenue and the 54" Keele Street trunk sewers.

Manning's equation was used to determine flowrates. The value of Manning's "n" was first determined by in-sewer measurements using the dye dilution method. Three calibration runs were made in the Hillary Avenue Sewer and the mean "n" value obtained was used in subsequent computations.

Flow depths were measured with portable level recorders mounted in manholes. The Hillary Avenue sewer was monitored from September 29-October 12, 1978 and the Keele Street trunk sewer from September 6-11, 1978. Sewer slopes were determined by survey.

Minimum wet weather flows producing overflows at the four major regulators (Keele/Donald, Keele/Dunraven, Hillary/Rogers, Hillary/Keele) were estimated by computing the flowrates for the maximum depths of flow in the trunk sewers corresponding to the regulator structure elevations.

4.2.2 Quality Determination

The quality of the dry weather flow was determined from composite samples, analyzed for chemical parameters, and grab samples, analyzed for bacteriological parameters. It was assumed that the quality of the sewage in the Hillary Avenue and Keele Street combined sewers was essentially identical, thus sampling activity was concentrated on the more accessible Hillary Avenue combined sewer.

Sampling of the Hillary Avenue combined sewer was carried out between September 30-October 14, 1977. An automatic sampler was used to gather 12-hour and 24-hour composite samples. The sampling interval was set at 20 minutes. Parameters analyzed in the collected samples were: BOD_5, COD, TSS, VSS, NH_3-N, NO_3-N, TKN, TP and Alkalinity as $CaCO_3$.

Sampling for bacteriological quality was carried out during the 1977 period of investigation. Samples were taken primarily from the Hillary Avenue combined sewer, and on one occasion from the Keele Street combined sewer. Samples collected were analyzed for fecal coliform, total coliforms and enterococcus bacteria.

All samples were taken to the Ministry of Environment Laboratory, Rexdale, Ontario on the same day they were sampled. All analyses were carried out according to the Laboratory Services Branch standard procedures.

4.3 CSO Tank System Measurements

The general layout of the tank monitoring system is shown in Figure 5. Both the existing tank level recorder and an additional bubbler level recorder were used for determining changes in the water level in the tank. Monitoring commenced in June, 1977 and continued until August, 1978. The relationship between tank level and volume was calculated from engineering drawings of the tank details.

The overflow rate from the CSO tank was calculated from the head on the tank effluent weir which was measured by means of a bubbler level recorder. Flows were computed according to the broadcrested weir formula:

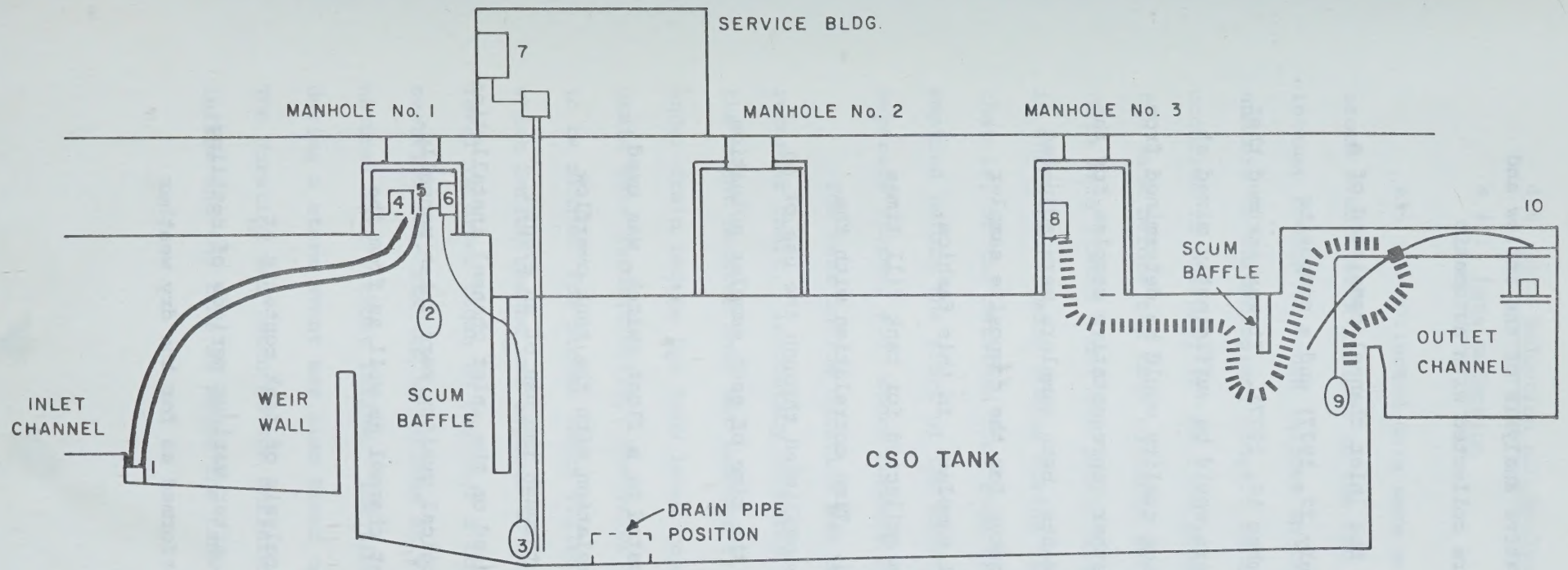
$$Q = CLH^{3/2}$$

where Q = flow in cfs

C = coefficient of discharge for broadcrested weir (5)
(= 2.77, 3.26 and 3.51 respectively for H = 0.5, 1.0 and 1.5 ft);

L = length of the weir crest in ft
(= 115.0 and 84.5 ft respectively for H > 2.0 ft and H < 2.0 ft);

H = head of water on weir in ft.



1 SAMPLING HEADBOX
2 HIGH FLOAT SWITCH (STOP SAMPLING)
3 LOW FLOAT SWITCH (START SAMPLING)
4 SIRCO SEQUENTIAL SAMPLER
5 MARKLAND COMPOSITE SAMPLER.
6 EVENT RECORDER
7 TANK LEVEL RECORDER.
8 OVERFLOW LEVEL RECORDER
9 OVERFLOW SAMPLER FLOAT SWITCH
10 SIRCO SEQUENTIAL SAMPLER

LEGEND

SAMPLING HOSE
BUBBLE PIPE
FLOAT SWITCH

Figure 5 Hyde Avenue tank : Monitoring instrumentation

Samples needed for qualitative analysis of the inflow and the overflow of the CSO tank were collected with automatic samplers.

The sampling equipment in the inlet channel consisted of a sequential sampler (installed July 22, 1977) and a composite sampler system (installed September 16, 1977). It was assumed that flows from the two incoming sewers would be sufficiently mixed at the sampling location that average quality could be determined from a single sample. In order to gather representative samples for the majority of significant storm events, both samplers were adjusted to a fast sampling rate, 2.5 minutes for the composite sampler and 5 minutes for the sequential sampler. In this fashion, adequate sample amounts would be collected for tank fill times from about 15 minutes to 2 hours. Time correlation with the tank level recorder data were accomplished through the use of an event recorder which registered the time of each sampler actuation on a continuous strip chart.

A sequential sampler, actuated by a float switch, was used at the overflow weir. Time correlation with the tank overflow level recorder was accomplished through the use of an event recorder similar to the device used on the inlet channel installation.

All samples for bacteriological quality were taken manually. Samples were taken from the inlet channel as well as from the tank.

Grab samples for quality analysis of tank contents at different depths were also taken after various periods of settling time. The same analyses were performed as for the dry weather flows in the sewers.

4.4 Data Reduction and Analysis Techniques

4.4.1 Data Reduction

All the collected data were assembled based on a list of storm events with inflows to the CSO tank. The storm events intense enough to cause inflows to the CSO tank were assigned numbers in chronological order. In a case in which two storms occurred in one day, if the flow from the second storm reached the tank before the tank contents were emptied, then the complete data were listed under one storm, e.g. storm number 26. In a case in which two or more storms during the same day had no interaction, that is, if the retained flow from the first storm in the tank was emptied before the start of the second storm, they were listed as separate storms, e.g. storm numbers 16A and 16B.

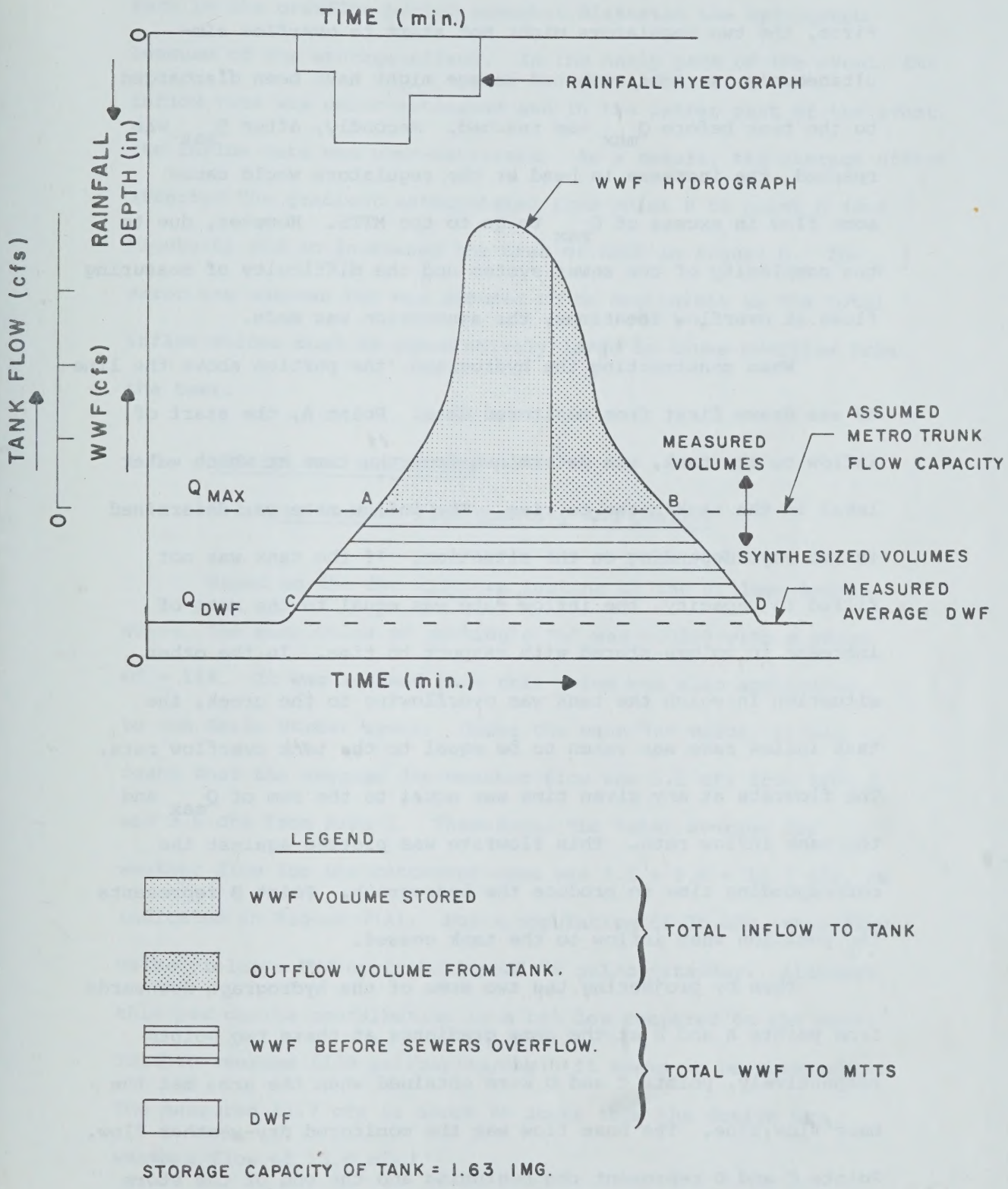
The tank inflow duration was obtained from the tank level recorder chart. Inaccuracy occurred during the initial period of the event because some wet weather flow was lost through the 12" under-drain before the tank level rose sufficiently to close the drain gate automatically. The error was unknown but was assumed to be minimal for storms which filled the tank. The instant at which inflow ceased was assumed to occur either when the tank level recorder began to register a constant level or when the overflow rate started to decline at what appeared to be the natural rate without inflow. The time taken to fill the tank during a storm event was also based on the level recorder data. The duration was taken as the difference between the start of inflow and the time at which the tank level reached 11.5 ft.

4.4.2 Method for Computing Wet-Weather Flow

The total wet weather flow for an event producing inflow to the tank was the sum of (i) flows going into the MTTS and (ii) flows going into the tank (which included the volume retained by the tank and the overflow volume, if any). Although the total quantity of tank inflow was readily determined from monitored data, there was no measurement of flow in the combined sewers such that either the volume going to the MTTS or the total wet weather volume of each storm event could be directly determined. The values of these latter two parameters were computed from a synthesized hydrograph similar to the one in Figure 6.

The hydrograph synthesis made use of the fact that the flow going to the MTTS was the sum of the flows in the two trunk sewers (the Keele Street sewer and the Hillary Avenue sewer) servicing tributary Areas 1 and 2, respectively. In wet weather, the flows in these two trunk sewers were determined by the maximum flow allowed to pass through the most downstream regulator at each of these sewers, i.e. regulators no. 3 and no. 6. By actual measurement, the maximum flows allowed by these two regulators were 39.3 cfs and 116.4 cfs, giving a total of 155.7 cfs.

It was then assumed in the hydrograph synthesis that the maximum flow, Q_{max}, going to the MTTS was 155.7 cfs and that any flow in excess of Q_{max} was diverted to the tank.



igure 6 WWF hydrograph.

The assumption involves two possible sources of error. First, the two regulators might not start to overflow simultaneously, so some combined sewage might have been discharged to the tank before Q_{max} was reached. Secondly, after Q_{max} was reached, the increase in head at the regulators would cause some flow in excess of Q_{max} to go to the MTTS. However, due to the complexity of the sewer system and the difficulty of measuring flows at overflow locations, the assumption was made.

When constructing the hydrograph, the portion above the line AB was drawn first from monitored data. Point A, the start of inflow to the tank, was determined from the time at which water level in the tank began to rise. The inflow rate was determined in two ways depending on the situation. If the tank was not filled to capacity, the inflow rate was equal to the rate of increase in volume stored with respect to time. In the other situation in which the tank was overflowing to the creek, the tank inflow rate was taken to be equal to the tank overflow rate. The flowrate at any given time was equal to the sum of Q_{max} and the tank inflow rate. This flowrate was plotted against the corresponding time to produce the hydrograph. Point B represents the position when inflow to the tank ceased.

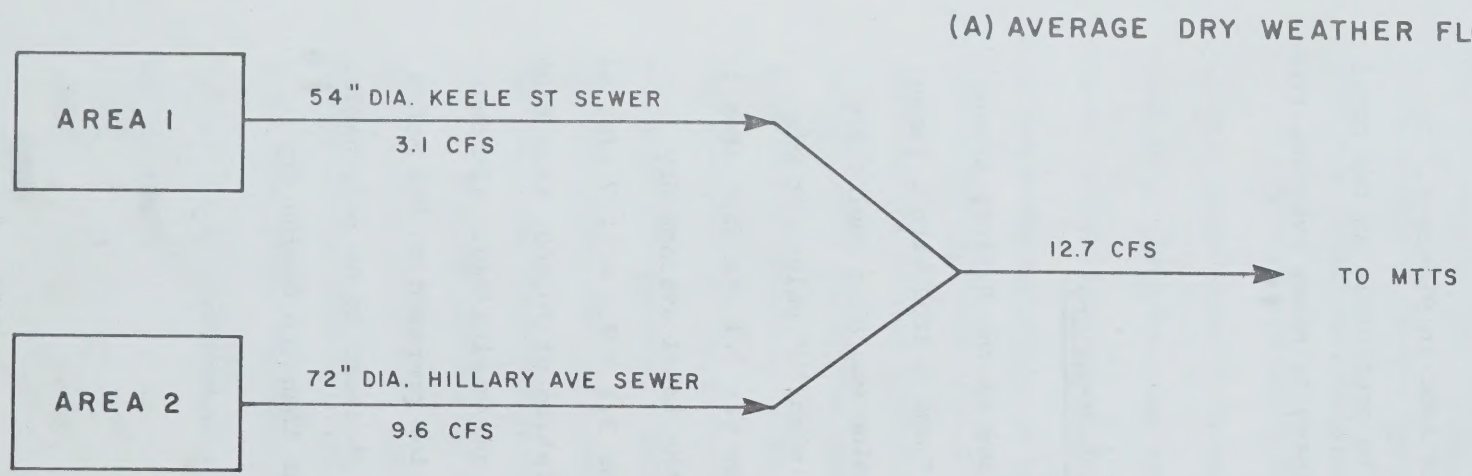
Then by projecting the two arms of the hydrograph downwards from points A and B at the same gradients at these two points respectively, points C and D were obtained when the arms met the base flow line. The base flow was the monitored dry-weather flow. Points C and D represent the beginning and the end of the storm event.

In theory, the equating of the inflow rate to the overflow rate in the overflow period somewhat distorted the hydrograph because of the storage effect. In the early part of the event, the inflow rate was under-estimated and in the latter part of the event, the inflow rate was over-estimated. As a result, the storage effect affected the gradient extrapolated from point B to point D (see Figure 6) and so increased the area of ABDC in Figure 6. The error was unknown but was assumed to be negligible as the total inflow volume must be comparatively large to cause overflow from the tank.

5.0 RESULTS AND DISCUSSION

5.1 Dry Weather Flow Quantity And Quality

Based on the dye dilution testing at the Hillary Avenue sewer, the mean value of Manning's "n" was 0.0209 with a range of $\pm$ 11%. It was assumed that this value was also applicable to the Keele Street sewer. Using the mean "n" value, it was found that the average dry-weather flow was 3.1 cfs from Area 1 and 9.6 cfs from Area 2. Therefore, the total average dry weather flow for the catchment area was 3.1 + 9.6 = 12.7 cfs, as indicated in Figure 7(A). For a population of 70,000, this flow value yields a DWF contribution of 98 gal/capita/day. Although this per capita contribution is a bit low compared to the Metro Toronto average (139 gal/capita/day), it seems to be reasonable. The measured 12.7 cfs is about 8% lower than the design dry weather flow of 13.8 cfs.


(A) AVERAGE DRY WEATHER FLOW
AREA 1
54" DIA. KEELE ST SEWER
3.1 CFS
AREA 2
72" DIA. HILLARY AVE SEWER
9.6 CFS
12.7 CFS
TO MTTS

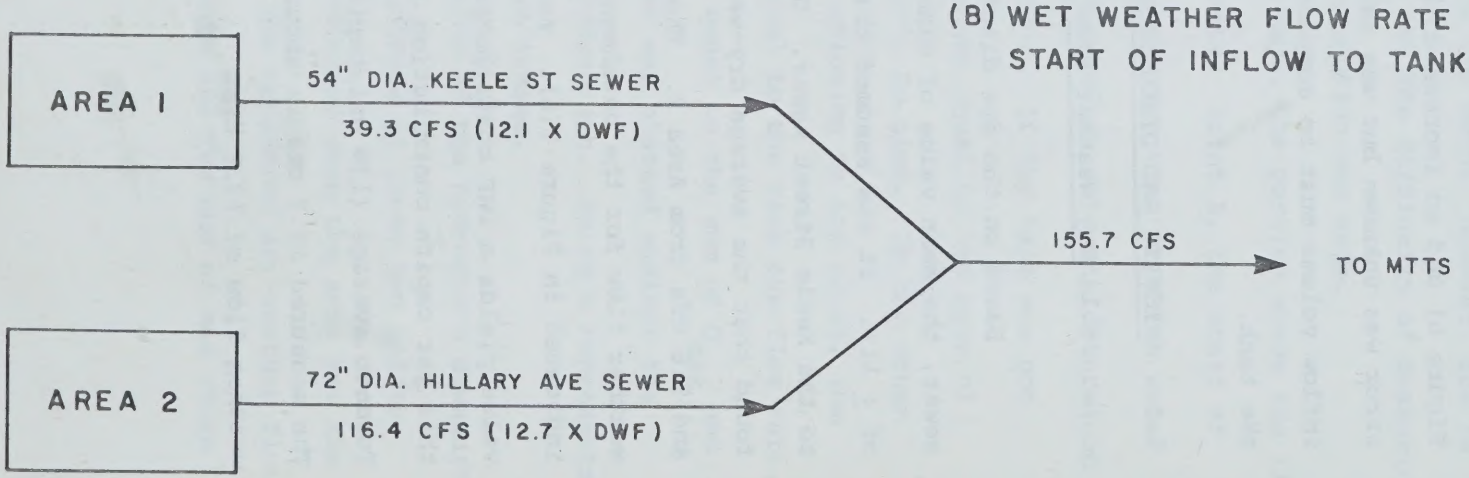

(B) WET WEATHER FLOW RATE AT
START OF INFLOW TO TANK
AREA 1
54" DIA. KEELE ST SEWER
39.3 CFS (12.1 X DWF)
AREA 2
72" DIA. HILLARY AVE SEWER
116.4 CFS (12.7 X DWF)
155.7 CFS
TO MTTS

Table 1 shows the dry-weather flow quality results for the 72" diameter Hillary Avenue sewer. Although daily readings are available for each parameter for the two-week sampling period, only the averages and the extremes are presented here. This Table also indicates the dry-weather flow bacterial densities for the same sewer. The quality results for the 54" diameter Keele Street sewer were similar to the Hillary Avenue findings. Due to the limited number of results, they are not presented. All results indicate a dry-weather flow quality typical for residential areas.

5.2 Rainfall

Examination of raingauge charts indicated that the two installed rainfall gauges recorded approximately the same rainfall quantities at about the same time. As a result, the data from each gauge was combined by a straight averaging of rainfall for each hour.

Fifty rainfall events were registered during the summers of 1977 and 1978. The average results for 1977 and 1978 are tabulated in Table 2(A). When compared to the 30-year historical precipitation data (Table 2(B)), it can be seen that in 1977, the rainfall of each month was higher than the 30-year average for the corresponding month. The 1978 rainfall was the opposite; both the depth of rainfall and the number of days with rain were below the long-term figures.

TABLE 1

AVERAGE DWF QUALITY RESULTS FOR HILLARY AVENUE SEWER

QUALITY PARAMETER	MAXIMUM (mg/L)	MINIMUM (mg/L)	ARITHMETIC MEAN (mg/L)	NUMBER OF SAMPLES
BOD_5	167	20	126	12
COD	334	113	278	12
SS	169	92	137	12
VSS	137	63	112	12
TKN (as N)	50	12	30	11
NH_3 (as N)	28	7.8	18	11
NO_2 (as N)	0.7	0.01	0.1	11
NO_3 (as N)	0.3	0.1	0.1	11
TOTAL PHOSPHORUS (as P)	10	1.4	4.9	10
ALKALINITY (as $CaCO_3$)	292	172	248	11

	MAXIMUM (No./100 mL)	MINIMUM (No./100 mL)	GEOMETRIC MEAN (No./100 mL)	NUMBER OF SAMPLES
FECAL COLIFORM	$6.5X10^6$	$0.7X10^6$	$3.1X10^6$	6
TOTAL COLIFORM	$1.5X10^8$	$0.7X10^8$	$1.2X10^8$	6
ENTEROCOCCUS	$4.7X10^5$	$0.9X10^5$	$1.9X10^5$	6

TABLE 2

RAINFALL RECORDS

(A) SUMMARY OF OBSERVED DATA, 1977-1978

	JUNE		JULY		AUGUST		SEPTEMBER		OCTOBER		SEASONAL TOTAL OR MAXIMUM	
	1977	1978	1977	1978	1977	1978	1977	1978	1977	1978	1977	1978
MONTHLY RAINFALL (INCHES)	2.94	0.68	5.23	1.41	4.00	1.64	5.01	NO DATA	2.88	NO DATA	20.06	3.73*
MAXIMUM 24-HOUR RAINFALL (INCHES)	1.65	0.34	1.17	0.64	0.99	0.37	1.62	NO DATA	0.89	NO DATA	1.65	1.17*
NUMBER OF DAYS WITH RAINFALL	4	5	8	6	13	8	13	NO DATA	5	NO DATA	43	19*

(B) 30-YEAR AVERAGE RECORD AT NORTHCLIFF STATION, 1941-1970

	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	MEAN SEASONAL TOTAL OR MAXIMUM
MEAN MONTHLY RAINFALL (INCHES)	2.53	3.20	2.81	2.35	2.50	13.39
MAXIMUM 24-HOUR RAINFALL (INCHES)	1.78	2.74	2.93	1.81	1.60	2.93
NUMBER OF DAYS WITH RAINFALL	9	8	9	9	9	44

* FOR JUNE TO AUGUST ONLY.

5.3 Wet-Weather Flow Quantity

5.3.1 Catchment And Sewer System Response

Figure 7(B) shows the results of measured wet-weather flows. It can be seen that the ratio of measured WWF/DWF 155.7/12.7 =12.3 indicates that an excessive quantity of combined sewage flows to the MTTS in wet weather. Typically, combined sewer systems are designed to accommodate 2.0-3.0 times DWF.

During the study period, thirty-three storms produced inflow to the tank. The rainfall volume over the catchment area yielded by the 33 storms was 856 IMG. The corresponding combined sewage volume, computed by the hydrograph method, was 371 IMG of which 335 IMG was stormwater runoff volume. The runoff to rainfall ratio was, therefore, 0.39. The distribution of the various flow volumes to the MTTS and the CSO tank during wet weather is shown in Figure 8.

5.3.2 Volumetric Performance Of Tank

Volumes and frequencies of wet-weather inflow to and overflow from the tank are summarized in Table 3 and diagrammatically shown in Figure 9.

It can be seen that the presence of the tank reduced the frequency of combined sewer overflow to the creek from 66% to 32% of all the storm events. In respect of frequencies, therefore, the improvement due to existence of the tank was significant. The less frequent combined sewage overflows to a receiving water directly, the more is the pollution problem contained.

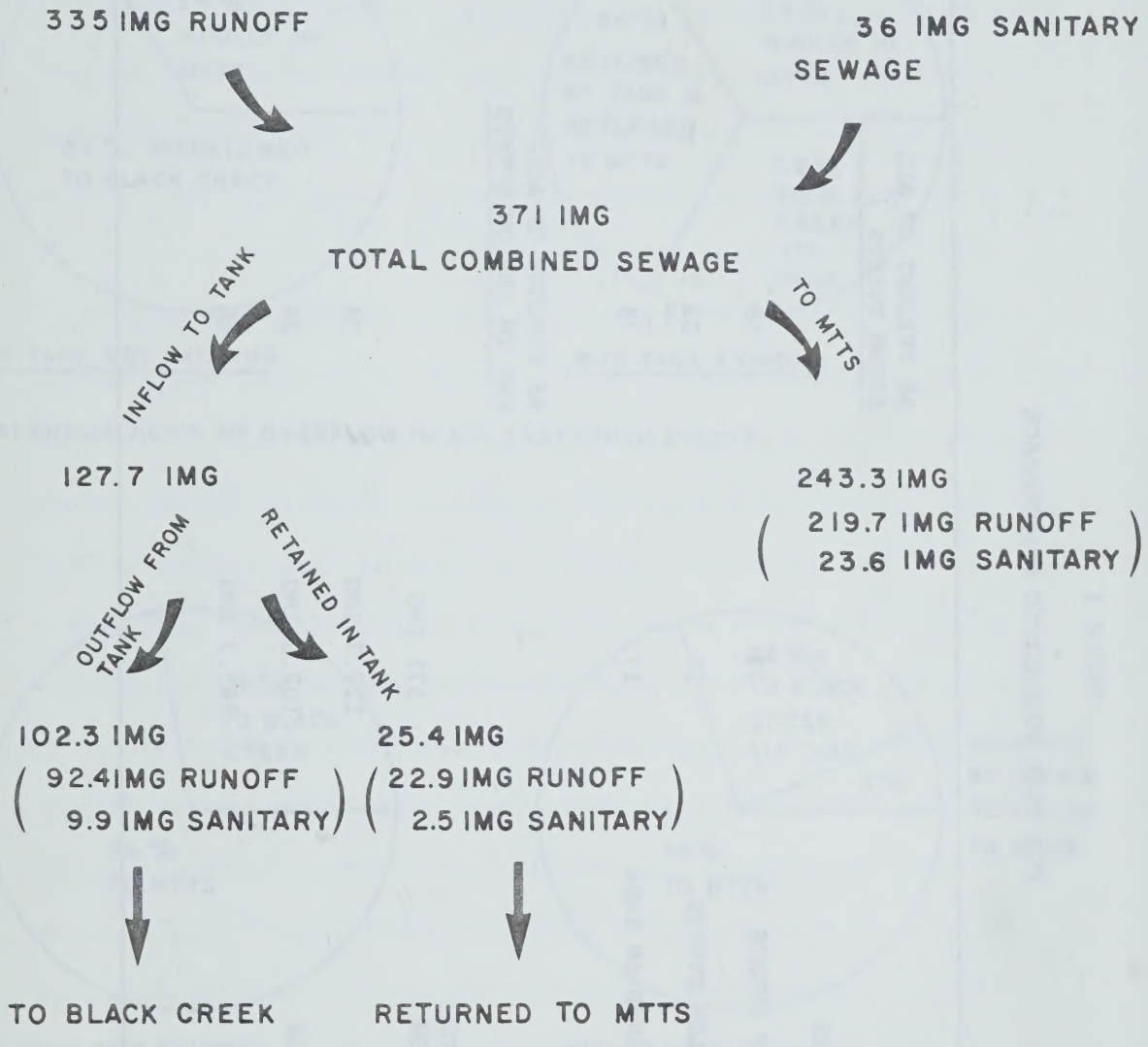


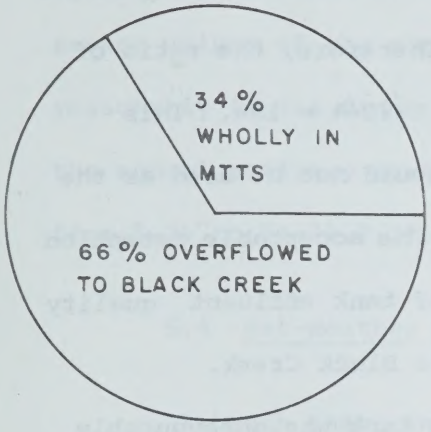
Figure 8 Distribution of flow volumes in events with tank inflow .

TABLE 3

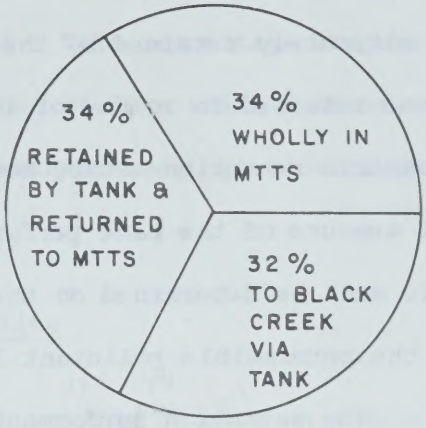
CSO TANK VOLUMETRIC PERFORMANCE

		AS PERCENT OF ALL STORM EVENTS
NO. OF STORM EVENTS	50	
NO. OF TANK INFLOW EVENTS	33	66
NO. OF TANK OVERFLOW EVENTS	16	32
NO. OF EVENTS RETAINED IN TANK	17	34

		AS PERCENT OF ALL WWF IN INFLOW EVENTS
TOTAL WWF IN EVENTS CAUSING TANK INFLOW	371 IMG	
TOTAL TANK INFLOW	127.7 IMG	34
TOTAL TANK OVERFLOW	102.3 IMG	28
TOTAL WWF TO MTTS	243.3 IMG	66

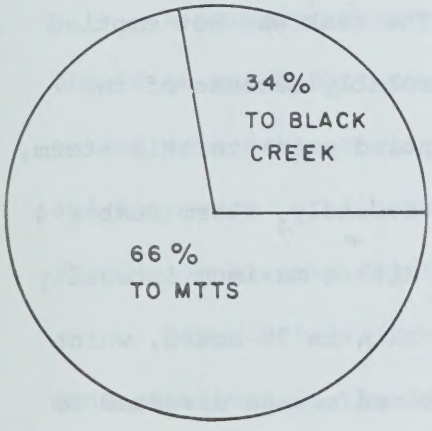


IF TANK NOT EXISTING

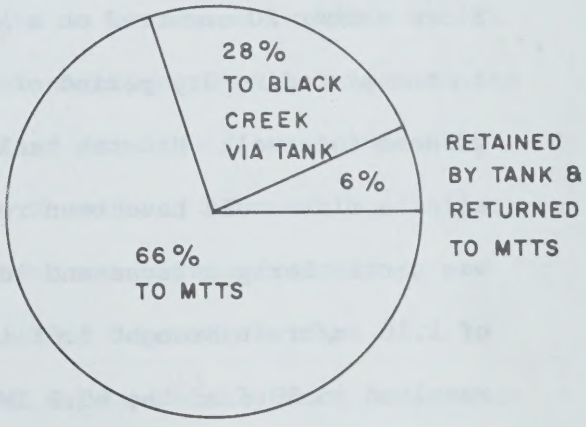


WITH TANK EXISTING

(A) FREQUENCIES OF OVERFLOW IN ALL (50) STORM EVENTS



IF TANK NOT EXISTING



WITH TANK EXISTING

(B) DISTRIBUTION OF COMBINED SEWAGE VOLUMES IN ALL (33) STORM EVENTS WITH TANK INFLOW.

Figure 9 Volumetric performance of CSO tank.

Thirty-four percent of the total wet-weather flow of all the events with tank inflow arrived at the tank and six percent was ultimately retained by the tank. Therefore, the ratio of volume retained to volume of inflow is 6%÷34% = 18%. This volumetric retention ratio, however, should not be used as the full measure of the tank performance. The acceptable retention ratio must be determined on the basis of tank effluent quality and the permissible pollutant loading to Black Creek.

The retention performance of the tank was unfavourably affected on two counts. First, during storm numbers 10 and 20, overflow occurred because the tank was already full at the start of the storm. The dry period preceding storm number 10 was too short to allow emptying of the tank before this storm started. Storm number 20 occurred on a Monday. The tank was not emptied in the preceding dry period of 2 days probably because of the weekend interval. Had the tank been emptied prior to this storm, all the flow could have been retained. Secondly, storm number 4 was particularly intense and lengthly. With a maximum intensity of 1.16 in/hr it brought 2.63 inches of rain in 7½ hours, which resulted in 58.6 of the 60.2 IMG of combined sewage diverted to the tank to be discharged to Black Creek. This storm had a return period between 50 and 100 years. The overflow volume of this storm accounted for 43% of the total overflow volume from the tank.

The sanitary sewage volume that overflowed to Black Creek was 9.9 IMG (Figure 8). It was 0.5% of the total sanitary sewage volume of the study period. This percentage compares reasonably to the findings of other studies which indicate that the annual sanitary sewage in combined sewer overflows ranges from 1.2% to 5% (1,2,3).

5.4 Wet-Weather Flow Quality

Although there were enough samples to give an indication of pollutant levels of the tank influent and effluent, simultaneous in/out quality data during the same storm were scarce. Consequently, it was difficult to estimate pollutant removal efficiencies of the tank operation.

A summary of quality results is presented in Table 4. It should be noted that the mean concentrations at the inlet and the outlet were not necessarily obtained from the flow concurrently and they were not flow-weighted. Therefore, the mean concentrations should not be compared for pollutant removal considerations.

Nevertheless, Table 4 serves to demonstrate that concentrations in the tank inflows were generally much lower than the mean concentrations of the dry-weather flow listed in Table 1. This fact can be attributed to the dilution brought by the runoff. The SS concentrations were an exception; they were higher during most storms than the sanitary sewage concentrations. A possible reason is the high content of grit and SS found in urban runoff. Another possibility is the scouring effect of the high wet-weather flows, which pick up most of the sanitary sewage deposits accumulated in the sewer during dry weather. Bacterial counts were generally two orders of magnitude lower than in the dry-weather flow.

TABLE 4

SUMMARY OF WWF POLLUTANT CONCENTRATIONS*

PARAMETER	ARITHMETIC MEAN (mg/L) TANK INLET	TANK OUTLET
BOD	44.0	31.2
SS	228.4	244.3
VSS	60.1	30.7
COD	165.9	140.0
ALKALINITY (as $CaCO_3$)	63.7	52.8
NH_3 (as N)	1.39	0.73
TKN (as N)	6.53	5.27
NO_2 (as N)	0.22	0.22
NO_3 (as N)	0.66	0.28
TOTAL PHOSPHORUS (as P)	1.50	0.97
	GEOMETRIC MEAN (NO./100 mL)	
FECAL COLIFORM	$1.2X10^4$	NO DATA
TOTAL COLIFORM	$1.3X10^5$	NO DATA
ENTEROCOCCUS	$9.3X10^3$	NO DATA

* SUMMARY OF DATA OF 19 STORMS

Concurrent influent and effluent quality data were obtained in only six storms, numbers 7, 16B, 18, 20, 26 and 28. Except in storm numbers 7 and 28, the tank overflow quality was generally better than the tank inflow quality, thereby indicating that tank retention helped to reduce pollutant levels. It is thought that in the case of storm numbers 7 and 28, quality samples of the tank overflow also contained flows from Black Creek which had backed up into the effluent channel. The fact that the tank overflow was visually much cleaner than the flow in Black Creek supports this opinion. The data of these two storms were rejected.

Storm number 26 was heavily polluted with average concentrations of BOD, COD, and SS ranging from 2 to 7 times the corresponding dry-weather flow pollutant levels. The high concentrations were felt to be due to scouring of the sewer.

The quality data of the four storms, numbers 16B, 18, 20 and 26 are listed in Table 5. The averages, including and excluding storm number 26, are presented for comparison. Since this is a very limited data base, the contribution of storm number 26 weighs heavily. As can be seen, the difference of average influent concentrations with and without this storm is very pronounced, whereas the effluent concentrations with and without this storm differ only slightly except for SS. Therefore, storm number 26 exerts a disproportionate influence upon the average removal efficiency. It should be noted that the average removal efficiencies listed in Table 5 are not derived from the average concentrations shown, but are the average of removal efficiencies of each storm. The BOD and SS removal percentages

TABLE 5

TANK INFLOW AND OUTFLOW QUALITY DATA

PARAMETER	(A) AVERAGES OF STORMS # 16B, 18, 20			(B) AVERAGES OF STORMS # 16B, 18, 20, 26		
	TANK INLET (mg/L)	TANK OUTLET (mg/L)	% REMOVAL*	TANK INLET (mg/L)	TANK OUTLET (mg/L)	% REMOVAL*
BOD	27.6	22.3	18.0	71.3	26.5	33.8
SS	166.0	137.3	15.7	383.5	233.8	24.2
VSS	46.3	30.7	32.7	46.3	30.7	32.7
NH_3 (as N)	0.56	0.77	(<0)	2.13	0.75	(<0)
TKN (as N)	4.9	4.7	3.3	10.9	5.0	22.5
TOTAL PHOSPHORUS (as P)	0.94	0.83	11.7	2.58	1.00	28.8

*ARITHMETIC MEAN OF % REMOVAL OF CONSTITUENT EVENTS.

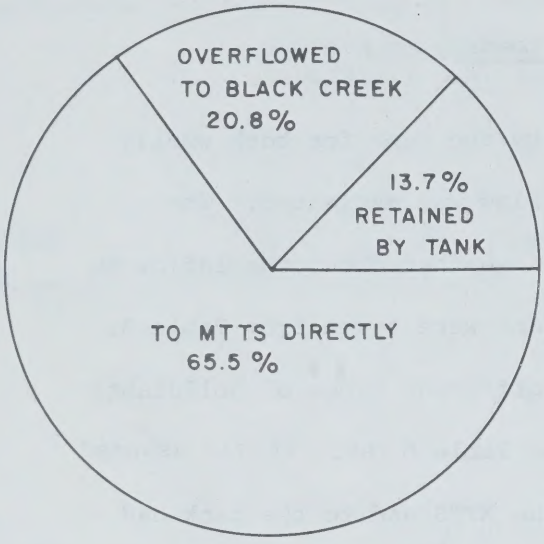
indicated in Table 5(B) compare favourably with the treatment results of the 193 IMGD detention facilities at Boston, Massachusetts (BOD and SS removal at 20% and 40% respectively) (6).

5.5 Reduction of Pollutant Loads

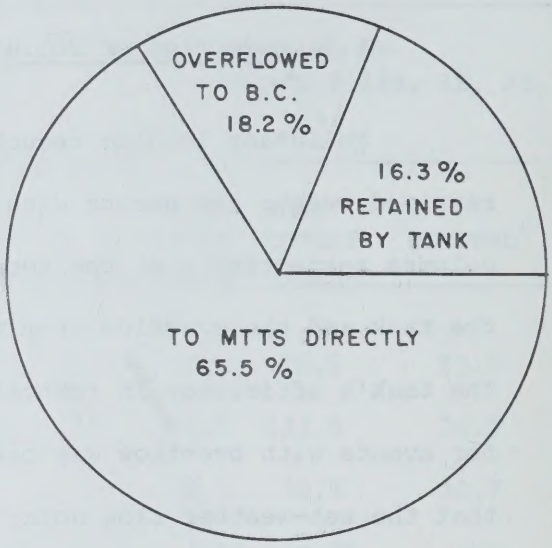
Pollutant loading reduction by the tank for both wholly retained events and events with overflow was estimated. The volumes respectively of the total wet-weather flow, the inflow to the tank and the overflow from the tank were taken from Table 3. The tank's efficiency in removal of different types of pollutants for events with overflow was based on Table 5 (B). It was assumed that the wet-weather flow going to the MTTS and to the tank had the same quality. The computed results are illustrated in the pie charts in Figure 10.

It can be seen from the pie charts that 34.5% of the pollutant load of each type entered the tank; the remaining 65.5% flowed directly to the MTTS. The pollutant loads wholly retained and/or removed during overflow periods by the tank ranged from 13.2% for TKN to 16.3% for BOD of the total influent loads. The corresponding load reduction percentages are tabulated in Table 6. These figures indicate that the tank is an effective device for reducing pollution from combined sewer overflow.

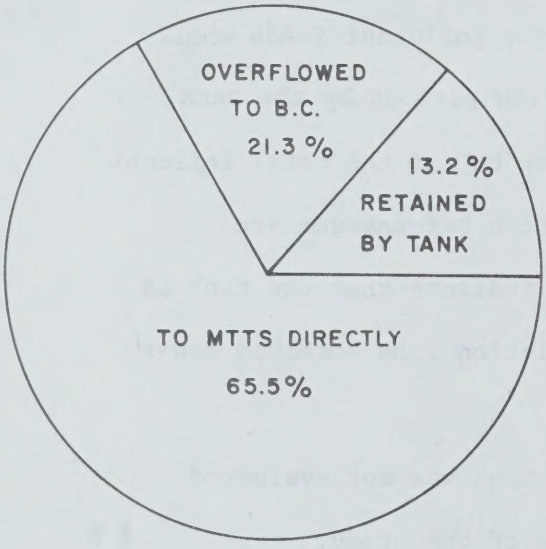
Long-term performance of the tank was not evaluated because the work was beyond the scope of the study.



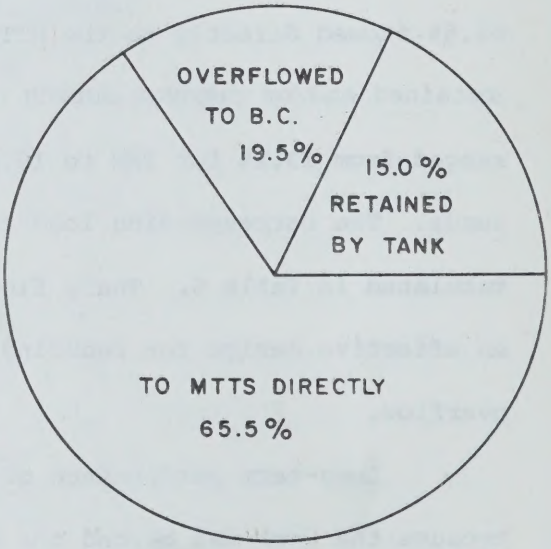
(A) SUSPENDED SOLIDS



(B) B O D



(C) TKN



(D) TOTAL PHOSPHORUS

Figure 10 Pollutant load reduction by CSO tank in all events with tank inflow.

TABLE 6

REDUCTION OF POLLUTANT LOADING

	TANK INFLOW LOADING* (a)	LOAD RETAINED BY TANK* (b)	POLLUTANT LOAD REDUCTION (c)=(b)÷(a)
SS	34.5%	13.7%	40%
BOD	34.5%	16.3%	47%
TKN	34.5%	13.2%	38%
TOTAL PHOSPHORUS	34.5%	15.0%	43%

* AS PERCENTAGE OF TOTAL LOADING FROM CATCHMENT, BASED ON FIGURE 10.

5.6 Bacterial Reduction

There was no adequate data for estimating bacteria reduction within the tank. However, due to the relatively short average retention time within the tank, little reduction through die-off was anticipated. Some reduction of seasonal bacterial loading was of course achieved because of the events wholly retained within the tank.

5.7 Visual Observations And General Comments

Based on visual observations, the grit quantities that collected in the tank inlet area were quite large, with the occasional 2 to 3 inch stone being included. This material was generally too heavy to be moved by the fire hose cleaning method or too large to be drained out to the MTTS, therefore, it was allowed to accumulate until it was removed by shovelling into a wheelbarrow. The wheelbarrow contents were then emptied into a large bucket, lifted to the surface, and hauled away by truck. Tank cleaning procedures appeared to be cumbersome and labour intensive, but any equipment or construction that may help improve the operation is unlikely to be highly cost-effective.

The sediment accumulated in the tank after storms were generally 1 to 2 inches deep and was a gelatinous material with some wood and paper mixed with it. The sediment would dry out between storms and become flaky and dusty. No odour problem was observed.

When the tank was full and overflowing, there was considerable floating material in the tank. Most of this material was kept behind the floatables barrier at the effluent end of the tank, so that very little floating material escaped to Black Creek. The barrier thus greatly enhanced the aesthetic quality of the overflow to the creek.

6.0 REFERENCES

1. Marsalek, J., "Abatement of Pollution Due to Combined Sewer Overflows", Inland Waters Branch, Department of Environment Canada, Technical Bulletin No. 66, 1972

2. Lager, J.A. and Smith, W.G., "Urban Stormwater Management and Technology: An Assessment", EPA-670/2-74-040, U.S. EPA Office of Research and Development, Cincinnati, Ohio, December, 1974.

3. Waller, D.H. and Novak, A., "Municipal Pollutant Loadings to the Great Lakes from Ontario Communities", Research Report No. 94, Canada-Ontario Agreement On Great Lakes Water Quality, 1979.

4. U.S. Army Corps of Engineers, "Urban Stormwater Runoff-Storm", Hydrologic Engineering Centre, Devis, California, January, 1975.

5. King, A.H. and Brater, E.F., "Handbook of Hydraulics", pg. 4-5, McGraw-Hill Book Company, New York, 1963.

6. Lager, J.A., "Urban Runoff Quantity and Quality", EFC/ASCE Conference Proceedings, American Society of Civil Engineers, pg. 99, 1974.

APPENDIX 1

RAINFALL AND FLOW DATA

APPENDIX 1 : RAINFALL AND FLOW DATA

1	STORM NUMBER	1	2	3	4	5	6	7
2	DATE	1/6/77	25/6/77	29/6/77	6/7/77	7/7/77	19/7/77	29/7/77
3	RAINFALL DURATION (MIN)	-	90	150	450	255	-	30
4	TOTAL RAIN DEPTH (IN)	-	1.19	.58	2.63	.24	-	.65
5	TOTAL RAIN VOLUME (IMG)	-	55.40	27	122.50	11.18	-	30.30
6	TOTAL WWF VOLUME (IMG)	-	13.8	10.06	91.50	-	5.33	7.68
7	TOTAL DWF VOLUME (IMG)	-	.474	.782	2.84	-	.427	.427
8	TANK INFLOW DURATION (MIN)	*	20	65	400	*	90	20
9	TANK INFLOW VOLUME (IMG)	*	9	2.61	60.19	*	.018	4.0
10	TANK OUTFLOW VOLUME (IMG)	#	7.37	.981	58.56	#	0	2.37
11	TANK RETAINED VOLUME (IMG)	-	1.63	1.63	1.63	-	.018	1.63
12	TIME BEFORE OVERFLOW (MIN)	#	12	30	120	#	N.A.	15
13	OVERFLOW DURATION (MIN)	#	8	35	280	#	0	5

EXPLANATION OF SYMBOLS: - NO DATA
* INFLOW OCCURRED
# ASSUMED NO OUTFLOW

APPENDIX 1

1	STORM NUMBER	8	9	10	11	12A	12B	12C
2	DATE	31/7/77	5/8/77	6/8/77	8/8/77	10/8/77	10/8/77	10/8/77
3	RAINFALL DURATION (MIN)	20	60	60	150	30	60	10
4	TOTAL RAIN DEPTH (IN)	1.13	.95	.26	.28	.41	.15	.11
5	TOTAL RAIN VOLUME (IMG)	52.63	44.3	12.1	13	19.1	6.99	5.12
6	TOTAL WWF VOLUME (IMG)	-	18.56	3.86	5.58	5.03	4.53	3.40
7	TOTAL DWF VOLUME (IMG)	-	.640	.427	.570	.214	.427	.308
8	TANK INFLOW DURATION (MIN)	*	60	30	60	20	60	40
9	TANK INFLOW VOLUME (IMG)	*	13.85	.176	.118	2.27	.025	.100
10	TANK OUTFLOW VOLUME (IMG)	-	12.22	.176	0	.640	0	0
11	TANK RETAINED VOLUME (IMG)	0	1.63	0	.118	1.63	.025	.100
12	TIME BEFORE OVERFLOW (MIN)	-	12	0	N.A.	18	N.A.	N.A.
13	OVERFLOW DURATION (MIN)	-	48	30	0	2	0	0

APPENDIX 1

1	STORM NUMBER	13	14	15	16A	16B	17	18
2	DATE	14/8/77	16/8/77	21/8/77	1/9/77	1/9/77	13/9/77	16/9/77
3	RAINFALL DURATION (MIN)	30	55	300	5	40	1260	300
4	TOTAL RAIN DEPTH (IN)	.34	.24	.59	.18	.45	.75	.60
5	TOTAL RAIN VOLUME (IMG)	15.84	11.2	27.5	8.40	21.0	34.9	27.9
6	TOTAL WWF VOLUME (IMG)	6.30	8.31	12.20	4.72	7.61	-	-
7	TOTAL DWF VOLUME (IMG)	.380	.712	1.00	.427	.380	-	-
8	TOTAL INFLOW DURATION (MIN)	20	105	135	60	50	105	*
9	TANK INFLOW VOLUME (IMG)	2.67	1.19	2.0	.114	3.70	.039	*
10	TANK OUTFLOW VOLUME (IMG)	1.04	0	.367	0	2.07	0	*
11	TANK RETAINED VOLUME (IMG)	1.63	1.19	1.63	.114	1.63	.039	-
12	TIME BEFORE OVERFLOW (MIN)	17	N.A.	85	N.A.	25	N.A.	-
13	OVERFLOW DURATION (MIN)	3	0	50	0	25	0	-

APPENDIX 1

1	STORM NUMBER	19	20	21	22	23	24	25
2	DATE	24/9/77	26/9/77	1/10/77	8/10/77	9/10/77	12/6/78	2/7/78
3	RAINFALL DURATION (MIN)	570	200	300	480	380	140	270
4	TOTAL RAIN DEPTH (IN)	1.61	.74	.92	.77	.35	.27	.35
5	TOTAL RAIN VOLUME (IMG)	75.0	34.5	42.9	35.9	16.3	12.6	16.3
6	TOTAL WWF VOLUME (IMG)	42.4	13.35	23	-	-	7.78	12.0
7	TOTAL DWF VOLUME (IMG)	3.0	1.04	1.78	-	-	.807	1.43
8	TANK INFLOW DURATION (MIN)	450	180	280	310	80	78	80
9	TANK INFLOW VOLUME (IMG)	10.90	.900	3.31	*	*	1.05	.573
10	TANK OUTFLOW VOLUME (IMG)	9.27	.900	1.68	0	0	0	0
11	TANK RETAINED VOLUME (IMG)	1.63	0	1.63	-	-	1.05	.573
12	TIME BEFORE OVERFLOW (MIN)	250	0	95	N.A.	N.A.	N.A.	N.A.
13	OVERFLOW DURATION (MIN)	200	180	185	0	0	0	0

APPENDIX 1

1	STORM NUMBER	26A 26B	27A 27B	28	29	30	TOTAL
2	DATE	21/7/78	26/7/78	2-3/8/78	15/8/78	16/8/78	
3	RAINFALL DURATION (MIN)	20+40	20+120	260	10	5	6160
4	TOTAL RAIN DEPTH (IN)	.11+.53	.08+.11	.58	.05	.17	18.37
5	TOTAL RAIN VOLUME (IMG)	5.12+24.7	3.73+5.12	27	2.30	7.90	855.64
6	TOTAL WWF VOLUME (IMG)	17.55	18.6	19.5	1.3	6.64	370.59
7	TOTAL DWF VOLUME (IMG)	1.09	1.70	1.64	.50	.64	36.06
8	TANK INFLOW DURATION (MIN)	95	165	240	45	60	2998
9	TANK INFLOW VOLUME (IMG)	6.00	.075	1.94	.187	.733	127.74
10	TANK OUTFLOW VOLUME (IMG)	4.36	0	.31	0	0	102.31
11	TANK RETAINED VOLUME (IMG)	1.63	.075	1.63	.187	.722	25.41
12	TIME BEFORE OVERFLOW (MIN)	20	N.A.	195	N.A.	N.A.	N.A.
13	OVERFLOW DURATION (MIN)	75	0	45	0	0	1171

APPENDIX 2

QUALITY DATA

APPENDIX 2

STORM NUMBER		1	3	4	5	7	9	11	12A	13	14
DATE		1/6/77	29/6/77	6/7/77	7/7/77	29/7/77	5/8/77	8/8/77	10/8/77	14/8/77	16/8/77
BOD (mg/L)	IN	28	8.5		3	22	11	26	32	72	28
	OUT					20		0			0
% REMOVAL						9		100			100
SS (mg/L)	IN	55	65	198	69	250	286	140	387	184	55
	OUT					342		0			0
% REMOVAL						-37		100			100
VSS (mg/L)	IN		24						102	53	31
	OUT								60		0
% REMOVAL									41		100
COD (mg/L)	IN	86	44	65	30	134	102	115	84	234	74
	OUT					190		0			0
% REMOVAL						-42		100			100
NH_3 (mg/L)	IN	1.5	.80	.70	<.10	.6	0.4	<.10	.83	2.2	1.0
	OUT					.8		0			0
% REMOVAL						-33		100			100
TKN (mg/L)	IN	3.2	1.8	3.3	1.5	4.2	2.7	3.2	5.1	6.8	4.0
	OUT					5.3		0			0
% REMOVAL						-26		100			100
ALKALINITY (mg/L)	IN	61	28	53	40	52	74		67	67	55
	OUT					74					0
% REMOVAL						-42					100

APPENDIX 2

STORM NUMBER	1	3	4	5	7	9	11	12A	13	14
DATE	1/6/77	29/6/77	6/7/77	7/7/77	29/7/77	5/8/77	8/8/77	10/8/77	14/8/77	16/8/77
NO_2 (mg/L) IN	.16	2.8	.02	.02		.06	<.01	.08	.02	.13
OUT					.01		0			0
% REMOVAL							100			100
NO_3 (mg/L) IN	.80	.45	1.5	1.1	<.1	.90	1.8	.60	<.10	.17
OUT					<.1		0			0
% REMOVAL					0		100			100
P (mg/L) IN	.56	.29	.58	.38	1.1	1.1	1.0	1.4	1.6	.89
OUT							0			0
% REMOVAL							100			100
FECAL COLIFORMS IN 1000/100 mL OUT	166	.018	.055	.043			890	710	570	670
TOTAL COLI. IN 1000/100 mL OUT	8,600	4,100		.968			19,000	23,000	8	2.1
										0
ENTEROCOCCUS IN 1000/100 mL OUT	60	.020	.300	.250			460	>15	135	240
INFLOW VOLUME (IMG)		2.61	60.19		4.00	13.85	.12	2.27	2.67	1.19
OUTFLOW VOLUME (IMG)		.98	58.56		2.37	12.22	0	.64	1.04	0

APPENDIX 2

STORM NUMBER		16B	18	19	20	24	25	26	27	28	AVERAGE
DATE		1/9/77	16/9/77	24/9/77	26/9/77	12/6/78	3/7/78	21/7/78	26/7/78	23/8/78	
BOD_5 (mg/L)	IN	32	28	39	20	50	56	205	90	42	44
	OUT	28	25		14	0	0	39	0	61	31
% REMOVAL		13	11		30	100	100	81	100	-45	54
SS (mg/L)	IN	241	181	120	76	330	214	1036	300	153	228
	OUT	221	119		72	0	0	523	0	189	244
% REMOVAL		8	34		5	100	100	50	100	-24	50
VSS (mg/L)	IN	62	55	68	22		124				60
	OUT	44	32		16		0				31
% REMOVAL		29	42		27		100				57
COD (mg/L)	IN	95	109	118	59	430	226	806	227	114	166
	OUT	77	91		48	0	0	161	0	273	140
% REMOVAL		19	17		19	100	100	80	100	-139	41
NH_3 (mg/L)	IN	.7	.6	2.2	.4	.9	2.1	6.8	3.1	1.4	1.4
	OUT	1.2	.6		.5	0	0	0.7	0	.60	0.7
% REMOVAL		-71	0		-25	100	100	90	100	57	51
TKN (mg/L)	IN	5.5	5.0	7.7	4.1	11	10	29	9.3	6.6	6.5
	OUT	5.7	4.4		4.0	0	0	5.7	0	6.5	5.3
% REMOVAL		-4	12		2	100	100	80	100	13	52
ALKALINITY (mg/L)	IN	53	47	62	46	82	67	164	80	49	64
	OUT	49	44		34	0	0	70	0	46	53
% REMOVAL		8	6		26	100	100	57	100	6	46

APPENDIX 2

STORM NUMBER		16B	18	19	20	24	25	26	27	28	AVERAGE
DATE		1/9/77	16/9/77	24/9/77	26/9/77	12/6/78	3/7/78	21/7/78	26/7/78	23/8/78	
NO_2 (mg/L)	IN	0.09	.06	.01	.02	.15	<.01	.03	.10	.15	.22
	OUT	0.20	.07		.02	0	0	.10	0	.90	.22
% REMOVAL		-122	-17		0	100	100	-233	100	-600	-52
NO_3 (mg/L)	IN	.5	.4	<.10	.9	1.0		<.1	.4	.90	.66
	OUT	.5	.3		.5	0		<.1	0	0	.28
% REMOVAL		0	25		44	100		0	100	100	81
P (mg/L)	IN	1.0	1.1	1.4	.72	2.6	2.1	7.5	1.9	1.2	1.5
	OUT	.9	.98		.62	0	0	1.5	0	.87	1.0
% REMOVAL		10	11		14	100	100	80	100	33	65
FECAL COLIFORMS 1000/100 mL	IN	.587		468	1.62						
	OUT				.08						
TOTAL COLIFORMS 1000/100 mL	IN	14.4	312	13.1	11.8						
	OUT										
ENTEROCOCCUS 1000/100 mL	IN	.39	28	119	15.6						
	OUT				.50						
INFLOW VOLUME (IMG)		3.70		10.90	.90	1.05	.57	6.00	.08	1.94	
OUTFLOW VOLUME (IMG)		2.07	Yes	9.27	.90	0	0	4.36	0	.31	

$ .02
6000 / 128.000
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